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SUBMARINE VERSUS SUBMARINES

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Naval Intelligence Support Center
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SUBMARINES VERSUS SUBMARINES

FOREWORD

The experience of two world wars has shown that submarines are a combat weapon which threatens the sea and ocean lines of communication and that their role, among other types of naval forces, is steadily growing. At the same time, they have proven to be quite effective as a means of conducting combat operations against other submarines.

The post-war introduction of nuclear power engineering into submarine building constituted a genuine revolution in the construction of submarines. Thanks to that new principle of power engineering, submarines have been converted from ordinary "diving" boats into "truly" underwater boats, with practically unlimited ranges and high speeds.

Along with the new atomic technology, submarines have begun to be equipped with very complex electronic gear and nuclear missiles, which have greatly increased their fighting power.

The leaders of the capitalist naval powers are exploiting those achievements in submarine building in their aggressive aims to create a powerful offensive weapon. At the present time in the United States, the building of an atomic submarine fleet is proceeding at a growing pace. England and France have begun building atomic-powered submarines, and there are plans for building them in the Netherlands, the Federal Republic of Germany, and Italy.

The United States, as the most powerful country of the capitalist camp in economic and military terms, holds the dominant position among all the aggressive blocs and imposes upon its military and political allies that path of military development which corresponds to the interests of the American imperialists, who dream of world domination.

The deepening of the common crisis of capitalism and the sharpening of its contradictions are intensifying the aggressiveness and adventurism of imperialism. Frightened by the growing strength of socialism, peace, and democracy, imperialism more and more seeks a way out in military provocations, plots, and direct military intervention. The barbaric war in Vietnam, the bandit assault against the Arab states by the Israeli aggressors, who were supported by world reaction and chiefly by the American imperialists, the military-Fascist revolution in Greece, and many of imperialism's other aggressive actions attest to its general policy of stepping up its aggressive operations.

A special danger to the cause of peace in Europe is the political-military alliance of the ruling circles of the United States and West Germany, which contribute to the revival of neo-Nazism and revanchism in West Germany. All of this is leading to a sharpening of international tension.

Modern American imperialism, which is feverishly preparing for war, has the most reactionary and aggressive character. From fiscal years 1946 to 1968, the United States spent approximately $1,050 billion on the arms race, double the expenditures for its entire history before 1945, including World Wars I and II. The arms race has been particularly intensified in connection with the escalation of the aggressive war in Vietnam. According to the United States military budget for fiscal year 1968/1969, $71.9 billion was allocated to the Pentagon, for more than three-fourths of the federal budget, and the tentative U.S. military budget for the fiscal year beginning 1 July 1969 provides an allocation of the astronomical sum of $102 billion for the Pentagon.

The political leadership and military command of the United States do not conceal their intentions to resolve a number of strategic problems in a war against the countries of the socialist camp with surprise nuclear attack upon the most important centers of the Soviet Union. The system adopted in the United States of continuous flights of aircraft loaded with atomic bombs and the patrolling of a large number of "Polaris" ballistic-missile submarines are part and parcel of those plans.

With that goal, the ruling circles of the United States are taking great pains to strengthen and expand their aggressive blocs and allies. They have established more than 2,200 military, air and naval bases, strong points, and other military objectives along the borders of the socialist countries.

The aggressive circles of the United States are making an effort to assign a basic strategic role in a future war to their naval forces. At the present time, more than one-third of the entire strategic nuclear potential of the American armed forces is concentrated in the atomic-submarine and aircraft-carrier fleet of the United States, and it is presumed that it will reach one-half by 1970.

As of 1 August 1968 the U.S. Navy had 76 atomic submarines, including 41 ballistic-missile submarines.

Western military experts consider that modern, ballistic-missile submarines are capable of inflicting powerful strikes from submerged depths against very important targets in an enemy's territory and, by these strikes, achieving strategic results which might have a decisive effect on the course and outcome of the war. In the recent past, the purpose of submarine combat was confined to securing safety of maritime passage and warding off the threat to ship navigation. Now, with the same degree of importance as the former missions, the chief purpose of that combat is the prevention of strikes against vitally important centers of the state. That means that under present-day conditions antisubarine warfare assumes strategic significance.

The military command of the United States and NATO attaches the highest importance in its strategic planning to the gradual build-up of combat forces and weapons by means of modern submarines and antisubmarine-warfare organization as a whole.

In the opinion of foreign experts, the search for a reliable means of striking at submarines is a prime problem of the U.S. Navy, and antisubmarine defense is considered one of the Navy's most important trends of activity in the very near future.

The proposed book summarizes the results of the military use of submarines by the capitalist countries in antisubmarine warfare, based on the experience of World Wars I and II. Also set forth are the views of military leaders of countries of the imperialist camp on the role, missions, and methods of using submarines in resolving the most important and complex problem of the U.S. Navy and Nato--combat with an underwater enemy.

Also examined are the present status and prospects for the development of attack submarines. The quantitative and qualitative characteristics of the submarine forces of the chief capitalist states are given, with a description of guidance systems, armament, and the communication-electronics equipment of multipurpose, and primarily atomic, submarines.

A number of articles have been published in recent years in the military journals of NATO countries devoted to the purpose of propagandizing the "technical superiority" of the arms of the U.S. Navy and of atomic submarines in particular. One must note that the unrestrained praise of American submarine technology by the western press has an obvious advertising and propaganda drift. Therefore, one must view with a critical eye all high-sounding foreign-press pronouncements about military technology.

Foreign experts should acknowledge that many models of military technology, including submarine equipment, have serious defects. Those defects are behind the unceasing accidents involving weapons and technical equipment on American atomic submarines at sea.

Thus, based on far from complete official information for the years 1960-1968, 54 accidents or catastrophes occurred on submarines of the leading capitalist countries. According to those gloomy statistics, 35 of those incidents took place on U.S. submarines during the period cited. Two of the accidents led to the loss of the atomic submarines THRESHER and SCORPION. Materials from the investigation into the cause of the loss of THRESHER, which in its day was extolled as a masterpiece of submarine construction, and of the SCORPION, attest to the fact that the leaders of the U.S. Navy, in the heat of the arms race, allow submarines with gross design errors to be intro-

duced into the fleet.

While preparing for a third world war, foreign apologists for military adventures cannot exclude from consideration the fact that the armed forces of the Soviet Union, including the Navy, are provided with an effective means of fighting any aggressor. Atomic submarines, armed with powerful nuclear missiles, have now become the foundation of our Navy. As the Commander-in-Chief of the USSR Navy, Admiral of the Fleet of the Soviet Union S. G. Gorshkov, has said, those submarines have high speed, great diving depth, and can operate in any, even the most remote, region of the ocean. Thanks to modern power engineering and powerful armament, our submarines are capable of coping with any combat task, including even successfully engaging in combat both the surface and subsurface forces of any aggressor. The strength of Soviet socialist power has been and still is the chief bulwark of peace on earth and the chief obstacle in the path of the imperialist warmongers.

Under present-day conditions, the strengthening of the defensive power of the Soviet Union is the unceasing preoccupation of our party. This was vividly expressed in the Summary Report of the Central Committee to the Twenty-third Congress of the Communist Party of the Soviet Union. The Party and Soviet people require of their fighting men persistent mastery of new technology and weaponry, and that they increase in every way their combat readiness for warding off of any aggressive actions of an enemy against our fatherland.

A study by Soviet naval personnel of the weapons of the navies of the imperialist powers, especially of the military applications of modern submarines and the theories of their use, will greatly enhance the training of our forces for combat with an aggressor.

The author made use of a variety of foreign and domestic open-source materials in writing this work. For their assistance with critical comments and advice during preparation of the book for publication, the author expresses his sincere gratitude to Comrades V. N. Alekseyev, A. T. chabanenko, V. N. Gerasimov, A. D. Denisov, A. A. Kvitnitskom, and Z. F. Slepenkov.

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Chapter IV

CONTROL SYSTEMS, WEAPONS, AND COMMUNICATIONS-ELECTRONIC EQUIPMENT FOR MODERN TORPEDO SUBMARINES OF CAPITALIST STATES

Control System

A characteristic feature of modern submarines is the sophistication of their equipment and the widespread use of automation in the control systems for the armament and installations of these ships. /88

According to the information in the foreign press, the introduction of automation was necessitated by the new approach that has been taken to the principles of the configuration of weapons and equipment, and of their arrangement in the compartments.

The experience of American experts in designing and building the last series of diesel submarines of the Barbel class in 1957-1959 is particularly indicative of this fact.

One particular problem has to be faced during the planning of these ships, that of automation, and how to eliminate the chief drawbacks in the control systems used earlier in submarines.

However, the answer to this problem called for a complex solution to a number of problems associated with combining equipment into a system, according to the purpose for which intended, with the location of the equipment in the compartments, and with the introduction of automated and remote controls for equipment and armament.

Research was undertaken to determine man's physical capacity to perceive and analyze the information received, and to determine the conditions that would simplify his efforts, in order to arrive at a correct structural solution to these problems.

Particular attention during the designing of the new control system was given to concentrating equipment and instruments directly involved in making

a torpedo attack and in shiphandling in a control room from which the submarine's commander could control the ship's movements and weapons. At the same time, it was necessary to remove auxiliary machinery from the control room, particularly the machinery generating a great deal of noise when running. /89

A radial design was adopted for the location of the control stations in the control room so the commander, or the watch officer, could observe from his station the performance of all operators, and the readings on all the main instruments. Indicating instruments and controls were grouped in a logical sequence by functional purpose (Figure 11). Control stations in other compartments too were modernized, within the limits of feasibility offered by the equipment.

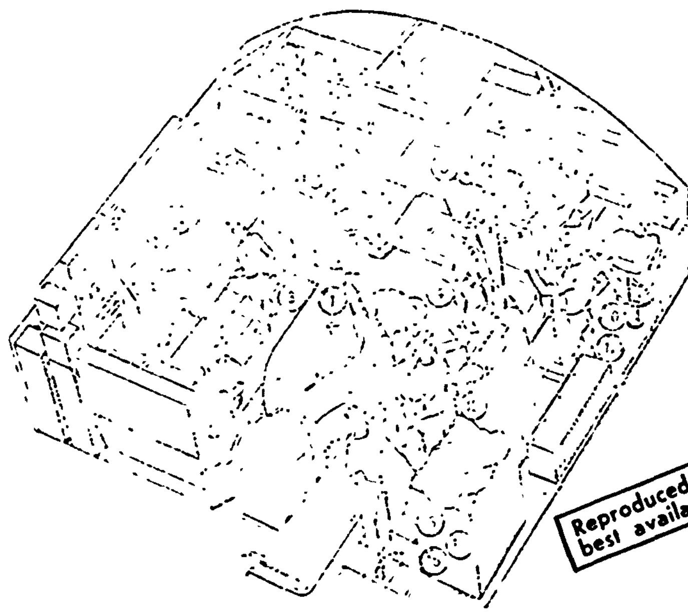

Figure 11. Barbel control room. 1 - submarine commander; 2 - mine-torpedo division officer; 3 - officer-in-charge of ship handling group; 4 - sonar officer; 5 - diving station operator; 6 - helmsman; 7 - relief helmsman; 8-11 - operators at navigation and combat information stations; 12-15 - torpedo fire-control instrument operators; 16 - computer operator.

The introduction of this system resulted in more than halving the number of personnel involved in handling a submarine of the Barbel class when making a torpedo attack, as compared to the number involved in previously existing classes of submarines of the same displacement, bringing the number down to between 13 and 16 men. /90

This control system, and the level of its automation, became the basis for the control systems adopted for the serially-built American multipurpose nuclear-powered submarines, and is the subsequent development of them (Figure 12).

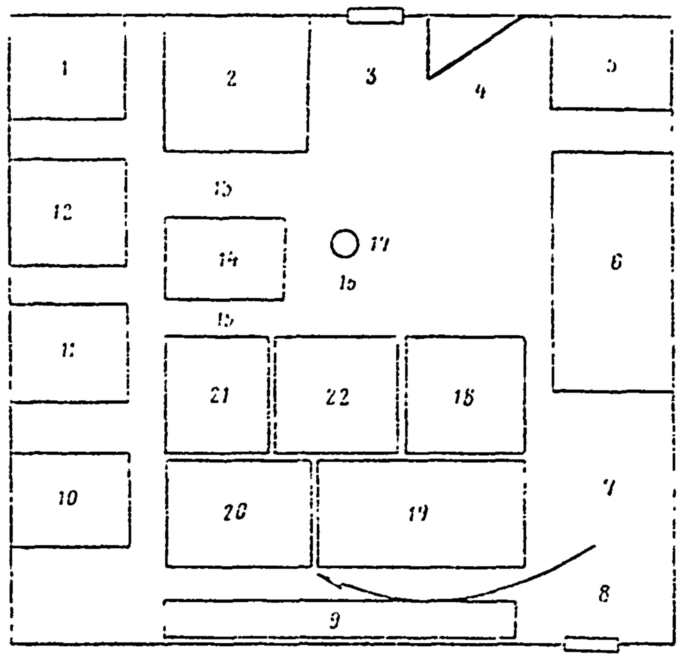

Figure 12. Control room of a nuclear-powered submarine of the Permit (Thresher) class. 1 - planesman's station; 2 - rudder, sail diving planes, and engine order telegraph control ; 3 - egress to bridge; 4 - transparent vertical plotting board; 5 - Mark 19 plotting table; 6 - Mark 113 automatic torpedo firing unit; 7 - AN/BQN-40 ice fathometer; 8 - door, 9 - communication equipment control console; 10 - AN/BPS-9 radar; 11 - AN/WLP-1 ECM equipment; 12 - diving station; 13 - engineer officer's station; 14 - radar repeater; 15 - navigator's station; 16 - torpedo officer's st. tion; 17 - periscope; 18 - AN/BQR-7 noise bearing repeater; 19 - SINS; 20 - AN/UQM-18 fathometer; 21 - Loran-A receiver; 22 - dead-reckoning tracer.

The arrangement of the armament into a complex, and the combining of all complexes into a common control system for a submarine by using automation and remote control, as in Barbel, drew the attention of experts in a number of the capitalist countries, and it was these principles that became the basis for the building and designing of submarines in a number of other states.

Thus, the control system adopted for the nuclear-propelled torpedo submarines in the British navy differs little from the American one. Work along these lines is in progress in Sweden, Italy, the Netherlands, and in other countries.

Reports in the foreign press indicate that the weapons and equipment for modern submarines, and their control and automation equipment, can be broken down into the following systems according to purpose: submarine movement; propulsion plant; torpedo and missile-torpedo firing; observation; target

designation and counteraction; navigation.

These systems have their own control stations, usually located in the control room, and these stations structurally are in the form of individual consoles with the necessary controls and instruments.

The special features of control consoles for systems and installations are:

grouping of control instruments and indicators in a logical sequence;

elimination of excess and distracting information; /91

location of switches and their indicators in direct proximity to to each other and their orientation in accordance with a unified principle;

logical correspondence between the direction in which control levers are moved and the resulting effect;

location of indicators requiring constant monitoring at operator eye level, or within 30° below his eye level; /92

location of instruments, the readings of which are used by several personnel on the upper part of the console;

the use of a dark mat background to ensure background contrast, with adaptation in the case of light indications taken into consideration;

the use of simplified indicators of different sizes and colors.

Accordingly, the movement control station in modern American submarines located in the control room consists of two instrument panels and controls for the first and second planesmen with a single, combined control for the planes and rudder, so that one man can control submarine course and depth. Both consoles are identical and are a redundant pair for controlling the rudder and planes through an electrohydraulic servo control. The second planesman is on watch to ensure safety of maneuvering of the ship at critical times.

Each planesman has an instrument board with indicators showing deviation from ordered course and depth, depth meters, gyro compass repeaters, and a dive rate and trim angle indicator. The planesman is oriented in the direction in which the submarine is moving.

Extensive changes have been made in the devices for controlling and monitoring such vitally important submarine systems as the high-pressure air system, the system for flooding and blowing the main and auxiliary ballast tanks, the hydraulic system, and others.

The foreign press notes that the introduction of electrohydraulic and electropneumatic remotely controlled valves and automatic devices has permitted

the combining of all the control stations for these systems at a single control station which, in American nuclear-powered submarines, is located in the control room. Monitoring and adjusting the control station instruments for these systems and devices provides information on readiness of the submarine to dive and surface, on its state of trim, and controls the blowing /93 and flooding of the main auxiliary ballast tanks, the trim system, the extendable installations, and the hydraulic system.

The accomplishment of all these measures makes it possible for one operator to man the systems and installations control station.

The systems and installations console is built in the form of several small-sized blocks and panels connected with contactors by cable connections for convenience of manufacture and repair.

The use of nuclear energy for submarine propulsion necessitated widespread use of automation and remote control, and this, in turn, necessitated finding solutions to a number of problems connected with the development and building of composite controls for a nuclear propulsion plant (NPP).

The control station for the nuclear reactor, and for the main and auxiliary propulsion plants, in the first American nuclear-powered submarines with the conventional automatic regulation was located in the control room of the 1950's. In submarines with a fully automatic NPP control system, the NPP control console has been removed from the control room and usually is located in the turbine room, or on the upper deck of the auxiliary machinery room.

The reactor, steam generating and machinery plants, and the electrical equipment are controlled from consoles at the control station. Operation of the main turbines, turbogenerators, circulator and lube oil pumps, is closely connected with the operation of the steam-generating plant.

Electrical signals proportional to the power generated by the geared turbine sets are generated continuously when the NPP is in operation. The operator, when it is necessary to change plant operating conditions, supplies a signal from the control console that is automatically compared with the signal proportional to the power being developed by the turbines. The result is the generation of a difference signal that is transmitted to the machinery controlling the position of the reactor's control rods.

Reactor operating conditions depend on the position of the control rods, /94 which, depending on the sign of the difference signal, automatically change position until the difference signal is zero. A zero difference signal means that reactor and turbine powers correspond to the ordered propulsion plant operating condition. Stability of this relationship is provided by internal feedback between the geared turbine sets and the reactor.

Today, U. S. Navy submarines have an improved automatic NPP control system. The main unit in the system is an electronic computer capable of regulating the operation of the entire complex of processes taking place in the propulsion plant.

According to reports in the foreign press, the U. S. Navy currently is working on a system for composite automation of submarine control that will, in the opinion of those in charge of the program, make it possible to reduce the crews of nuclear-powered submarines by a factor of 8 to 10, and reduce their complements to 10 or 12 men. Plans call for further automation of control of submarine movements, of the propulsion plant, communications, armament, and air regeneration installations. It is anticipated that all these systems will be combined into a single complex, control of which will be exercised from a commander's console.

All of the great deal of incoming numerical data needed for calculations when controlling the submarine should be analyzed by electronic computers and read out in the form of visual position images in order to simplify the actions of the man controlling the submarine.

Thus, the commander's console should become the main link in the new control system. The external and internal situation relative to the ship should be reflected on the screen of the commander's conso. .. This centralized submarine control system is being developed by the Electric Boat Company under the designation SUBIC [submarine integrated control] (Figure 13).

One of the most important devices in the system developed for controlling /95
the movements of a submarine is the television indicator known as CONALOG [contact analog], which reproduces a visual image of the ship's movements in space. It simplifies controlling submarine course and depth.

Figure 13. Mockup of the SUBIC control station.

According to the reports in the foreign press, the CONALOG indicator system underwent shipboard trials in the nuclear-powered torpedo submarine Shark in 1961. Serial production of this equipment has begun, and new construction submarines will be the first to be given the equipment.

The CONALOG television indicator is a complex electronic system with a computer, into which is fed information from the course, speed, depth, and sonar transmitters. All of these data are converted by an electronic generator and are indicated on a 48.3 cm screen in the form of a conventional visual

picture of the movement of the submarine along its assigned course and at its assigned depth relative to the surface of the water, the lower edge of the ice cover and maximum operating depth, or ocean bottom. The helmsman sees three planes on the red lighted screen so the data are in perspective and the illusion of a three-dimensional image is created.

The upper plane is the surface, the lower is at the maximum operating
depth, or at the ocean bottom. The upper and lower horizontal planes /96
intersect a vertical plane with a dark hue. A lighted horizontal line passing through the vertical plane, the so-called horizon, indicates the ordered depth.

Reflected on the screen as well is a relatively brightly lighted long strip, or, as it is called, a "roadway." Moving black strips, which come toward the helmsman more or less rapidly, depending on ship's speed, are positioned across the lighted strip. The "roadway" indicates the predetermined trajectory over which the ship is to move in the horizontal plane.

If, for example, the submarine is running at a depth less than that ordered the "roadway" will contract, as if moving downward, away from the planesman, and when the submarine is running at a depth deeper than that ordered the "roadway" appears to the planesman as if it were above him. If the submarine's course is changed to port, the "roadway" bends to port, and vice versa. When the helmsman returns the submarine to its ordered course the "roadway" straightens out.

The submarine's bow shows on the screen as a glowing cross (+). When the center of the cross coincides with the horizon line the submarine is carrying no trim.

If the cross is seen above. or below, the horizon, the submarine is trimmed by the stern, or by the bow, respectively.

The submarine's commander, or the watch officer, issues orders to the planesman, feeding into the electronic image generator the ordered values for course and depth. The horizon line on the screen now moves to the required depth and there is a simultaneous change in the position and shape of the "roadway."

The CONALOG system, in addition, provides automatic control of the submarine's ordered course and depth, as well as of the ship's maneuvers in accordance with a preplanned program.

A warning sounds if the automatic control fails, and the system automatically reverts to manual control.

Training in the use and operation of the new system began in the Sub- /97
marine School, New London, in October 1964.

It is proposed that in the future data from the navigation equipment and weapon control system be fed to the indicator section of the CONALOG system.

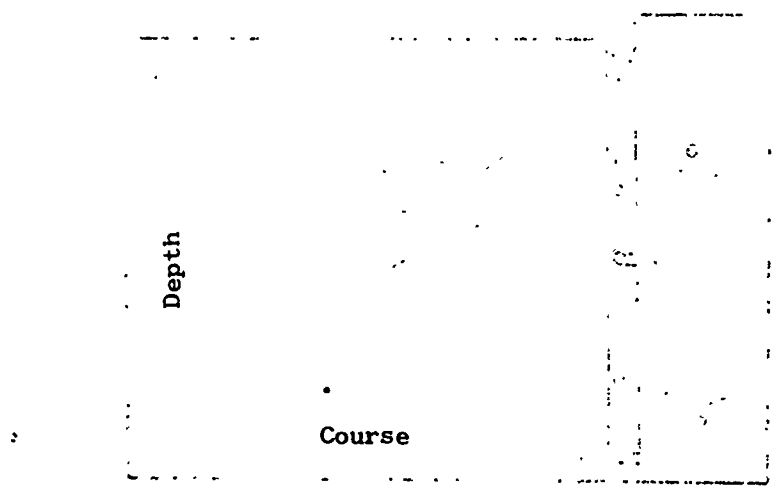

Figure 14. The screen of SQUIRE, a system for presenting a visual image of the surrounding situation. 1 - true position of submarine; 2 - moving point; 3 - ordered position of submarine; 4 - moving strip; 5 - rudder angle indicator; 6 - trim indicator.

Another, similar, system of visual presentation of the surrounding situation, replacing conventional meters and dials, is the SQUIRE system (SQUIRE - Submarine Quickened Response). The screen (Figure 14) has a grid with depth plotted on the y-axis, course on the x-axis. Crosses and points show the actual and intermediate positions of the submarine. The watch officer, when he must change course or depth, feeds the necessary orders into the system and a circle indicating the position the submarine should /98
be in appears on the screen.

The helmsman uses the control system lever to match the point and the circle, and the submarine assumes the new course and depth. When the submarine is in the ordered position the cross on the screen's indicator moves into the circle containing the point. This system has no speed indicator on it screen, but as distinguished from the CONALOG system displays everything that takes place around the submarine in any direction, not just what is going on in the ahead direction on the course over which the submarine is moving. It is the opinion of the foreign experts that the SQUIRE system is an improvement over other systems for providing visual displays of the situation.

The foreign press points out that the effectiveness of any submarine control system is greatly dependent on the arrangements for exhibiting the data on the situation, the elements of submarine movement, and simplicity of its controls. The introduction of electronic and automation equipment will, in the final analysis, make possible a reduction in submarine crews.

The highest level of automation among the capitalist states has been reached in the American submarine fleet. Automated equipments are under

development and their introduction is proceeding rather slowly in submarine building in the other countries, and are, in part, replicas, with certain modifications, of systems used in the American navy.

Torpedo Armament

Multipurpose submarines of the principal capitalist states built during the postwar period usually have 4 to 8 533 mm torpedo tubes.

A trend toward a reduction in the number of torpedo tubes is noted. Skate and Skipjack classes have six torpedo tubes, but beginning with the Permit class the submarines have four tubes. The tubes are installed amidships and are at an angle of 10° (20° according to other information) to the centerline plane.

All U. S. Navy submarines have hydraulic firing systems for their torpedo tubes. The torpedoes are ejected from the tubes by pneumatic-hydraulic rams (Figure 15). Foreign experts are of the opinion that this system generates less noise when fired and allows firing to take place at any depth, up to maximum. /99

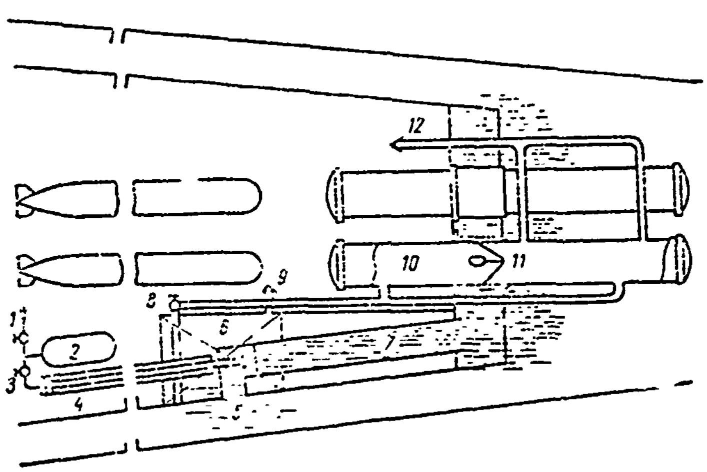

Figure 15. Hydraulic torpedo tube arrangement. 1 - line from high-pressure air system; 2 - impulse flask; 3 - firing valve; 4 - air flask for pneumatic-hydraulic ram; 5 - overboard valve; 6 - water-round torpedo tank; 7 - water cylinder for pneumatic-hydraulic ram; 8 - tube flooding and drain valve; 9 - water-round torpedo tank blow and vent line; 10 - torpedo tube; 11 - tube water supply valve; 12 - torpedo tube blow and vent line.

It is pointed out that the drawback in hydraulic torpedo tubes is poor weight and size characteristics as compared to tubes with an air firing system, and serves to explain why submarines in most foreign fleets have torpedo tubes with air firing systems.

The nuclear-powered submarines in the British navy have hydraulic torpedo tubes arranged in a manner similar to that in American submarines.

Modern submarines in foreign fleets have special torpedo loading gear, and automated gear for reloading the tubes. The nuclear warheads for torpedoes, and for ASW guided missiles, in American multipurpose nuclear-powered submarines are monitored by a special system called the Mark 18. This system includes devices to prevent the accidental firing of the torpedo tubes and to signal incorrect handling of the weapon, as well as equipment for monitoring radiation in the spare torpedo stowage. /100

The main battery of modern torpedo submarines in foreign fleets comprises homing torpedoes and wire-guided torpedoes, and, in addition in the U. S. Navy, SUBROC, the ASW rocket.

Foreign experts evaluate wire-guided torpedoes as one of the most important improvements in underwater weaponry in the postwar period. There is no need for precise data on the movement elements of an underwater target, or to calculate the advanced point of fire, in order to fire these torpedoes. The torpedo can be fired on the present bearing, or on the basis of approximate data, and then its course to the target can be corrected over the wire (Table 15). This improvement allows these torpedoes to be fired immediately after the detection and classification of the contact, increasing the probability of destroying the underwater enemy.

A number of the capitalist navies have been giving a great deal of attention to creating new types of torpedoes primarily antisubmarine, with high performance characteristics for submarines.

The Mark 37 electric torpedoes are the principal type of antisubmarine torpedoes envisaged for use by submarines in the U. S. Navy.

All modern United States submarines, and those of some of the NATO countries, have Mark 37 torpedoes, with only some of them having the Mark 27 (Mod. 4), which will be replaced by the Mark 37. Foreign experts are of the opinion that the Mark 37 torpedo is quite modern. The Mark 37 torpedo /103
should be replaced by the Mark 48 (formerly the EX-10) torpedo now under development and which has a better guidance system and wire guidance. This torpedo is designed to fight deep-running nuclear-powered submarines and will have many advantages as compared to existing torpedoes.

All of the above-indicated marks of torpedoes are fitted with conventional warheads with a highly destructive high-explosive charge.

The armament of U. S. Navy submarines includes the Mark 45 (ASTOR) wire-guided electric torpedo with a nuclear warhead with a TNT equivalent of 10 kt. The experimental Mark 39 torpedo was conceived at the beginning of the 1950's for purposes of perfecting methods of submarine torpedo firing when using wire-guided torpedoes. Despite the fact that some 200 Mark 39 torpedoes were produced, this torpedo never has been considered a combat weapon.

The foreign press has acknowledged the fact that today the firing range of torpedoes with a hydroacoustic homing system has increased very little as compared to that for the first homing torpedoes at the end of World War II, but the reaction range of the homing system used in the torpedoes has increased to 1000-1500 meters.

Table 15. Performance Data for Antisubmarine Torpedoes for United States Submarines

a Марка торпеды (год принятия на вооружение)	b Калибр/длина, мм	c Скорость, уз/Дальность, м	d Вес торп., кг	e Глубина хода, м	f Взрыватель	g Тип двигателя. Источник энергии	h Система наведения	i Примечание
j Мк-27 мод. 4	482/3180	•/•	531	•	•	r Электродвигатель. Аккумуляторы	x Гидроакустическое пассивное самонаведение	D Выходит из торпедного аппарата своим ходом
k Мк-37 мод. 0 (1953)	482/3130	30/10000	•	•	p Контактный	s Электродвигатель. Аккумуляторы на морской воде	y Гидроакустическое пассивно-активное самонаведение	
l Мк-37 мод. 1 (1961)	482/4050	30/7000	•	•	q То же	t То же	z Управление по проводам и гидроакустическое пассивно-активное самонаведение	
m Мк-39 (1958)	533/•	•/9000	•	•	•	u Электродвигатель. Аккумуляторы	A Управление по проводам и гидроакустическое самонаведение	E Опытный образец
n Мк-45 „Астор" (1961)	482/5770	40/18000	1080	15—300	•	v Электродвигатель. Аккумуляторы на морской воде	B Управление по проводам	F Мощность БЗО до 10 кт
o Мк-48 (разрабатывается)	482/6000	over 40/•	1360	over 400	•	w РДТТ, газовая турбина	C Управление по проводам и гидроакустическое самонаведение	G Разрабатывается по программе „Retore-2"

LEGEND for Table 15:

a - Mark torpedo (year added to arsenal)
b - Caliber/length, mm
c - Speed, knots/Range, m
d - Weight, kg
e - Running depth, m
f - Exploder
g - Type engine. Power supply
h Guidance system
i - Note
j - Mark 27 Mod. 4
k - Mark 37 Mod. 0 (1953)
l - Mark 37 Mod. 1 (1961)
m - Mark 39 (1958)
n - Mark 45 ASTOR (1961)
o - Mark 48 (under development)
p - contact
q - same

r - Electric motor. Storage batteries.
s - Electric motor. Storage batteries in sea water.
t - same
u - Electric motor. Storage batteries.
v - Electric motor. Storage batteries in sea water.
w - Solid fuel rocket engine. Gas turbine.
x - Hydroacoustic, passive, homing
y - Hydroacoustic passive-active homing
z - Wire guidance and hydroacoustic passive-active homing
A - Wire guidance and hydroacoustic homing
B - Wire guidance
C - Wire guidance and hydroacoustic homing

LEGEND for Table 15 continued:

D - Leaves tube on own power
E - Experimental model
F - 10 kt warhead
G - Under development in the "Retorc-2" program

Other of the capitalist countries, particularly England and France, too have for several years been engaged in the development of antisubmarine torpedoes with wire-guidance designed for use by submarines.

All antisubmarine torpedoes included in the arsenals of the navies of the principal capitalist states have noncontact exploders.

Foreign scientific-research and design organizations today are working on building the weapon with the capability to destroy not only existing submarines, but those that will be built in the future as well. It is taken that antisubmarine torpedoes should be fast, run deep, be highly maneuverable in all directions, and have a comparatively low own noise level. /104

The attempt to bring about a substantial increase in the speed at which the charge is delivered to the target can be explained by the fact that success in attacking a high-speed submarine is directly proportional to the weapon-submarine speed differential. American experts believe torpedo speed should be five times that of the submarine the torpedo is tracking. This means a 150 knot torpedo for attacking a submarine running at 30 knots. The possibility of the future development of silent, wakeless torpedoes with ranges of 150-180 km, and speeds of 300-350 km/hr, is suggested. A torpedo such as this could be built with the economical ram or pulse hydrojet engine as the basis. According to reports in the American press, one version of this jet engine was tested in a torpedo in 1966.

Foreign experts believe that antisubmarine torpedoes today should kill underwater targets at 300 meters and deeper. Work is in progress to increase these depths by a factor of 2 to 4. However, the increase in the depth to which modern submarines can descend increases their evasion capability, and makes the operation of the detection and guidance instruments difficult.

Improvement in the maneuverability of antisubmarine torpedoes too is being given a great deal of attention. Torpedoes have comparatively small hulls and can be made much more maneuverable than submerged submarines. Yet despite the fact that maximum submarine acceleration (or deceleration) is not very great, the submarine still has the capacity to make substantial changes in speed, course, and depth between the time of last fix of the submarine's position obtained from the fire-control instruments and the torpedo hitting the target, and this reduces the efficiency of the weapon, which does not have sufficient maneuverability.

The requirements for a reduction in the noise generated by the torpedo is occasioned by the need to avoid detection of torpedoes by the sonar gear installed in the target submarine and thus preclude the possibility of the latter taking counter or evasive action, as well as by the attempt to increase

the efficiency of the torpedo guidance system. /105

The first nuclear-propulsion plants for United States submarines were very noisy. This drawback has gradually been eliminated in the modern submarines, and this has led to the need to attempt to develop attack type torpedo control and guidance systems.

The substantial increase in the maximum submarine operating depth, and the increase in hull strength, have made it necessary to increase explosive power of torpedo warheads. This can be explained by the fact that at depths less than maximum modern submarines have a high hull strength safety factor.

Foreign press reports suggest that serious problems arise in connection with the possible use of nuclear charges in an antisubmarine weapon. The radius of destructive effect of these charges is extensive and when fired can make up for numerous errors. Water is 800 times as dense as air, so a large explosion creates a compression wave that can be propagated in the water over a long distance.

It should be noted that it was not too long ago that all that was needed to sink a submarine was to set off a charge weighing 2 tons within 10 to 11 meters of the submarine's hull. Now a torpedo with a nuclear warhead with a TNT equivalent of 2,500 tons can sink a submarine when it explodes 610 to 915 meters away. The kill radius will increase with increase in the power of the nuclear charge.

But it is reported that the majority of targets initially identified as submarines prove to be false identifications. At one time this simply resulted in the useless expenditure of much of the antisubmarine weaponry. Now, unless new, more dependable, methods of identifying underwater targets are found, the indiscriminate use of antisubmarine weapons with nuclear heads. for purposes other than those of actual need can have dangerous consequences, including a very high level of radioactive polluted water.

Thus, many factors, that have an influence on the effectiveness of the antisubmarine weapon, and particularly the status of development of hydro- /106
acoustic gear for submarines, and their noisiness, as well as the characteristics of the noise generated by the torpedoes, their speed and range, running depth, and radius of reaction of their guidance systems, are taken into consideration in the development of the principal parameters of modern torpedoes.

Foreign experts are giving a great deal of study to the possibility of using the infrared (heat) principle in torpedo guidance systems.

Mines have a large place in the arsenal of antisubmarine weaponry. It is considered that the use of mines by submarines can be extremely effective, particularly when mines are laid in areas used by submarines as they depart their bases, as well as in restricted pilot waters. The U. S. Navy was completing its tests of the Mark 57 moored antisubmarine mine at the end of 1963. This weapon had been designed specially for laying by a submarine. It should be pointed out that Americans consider mines to be an antisubmarine weapon used primarily against single submarines and consider it undesirable to fit them with nuclear charges.

Nuclear-powered American submarines added the antisubmarine missile SUBROC to their arsenal in 1965. Each submarine, it has been proposed, will have from four to six of these missiles. The missile can be used with a nuclear, or conventional, charge and is designed primarily for fighting high-speed, highly maneuverable, nuclear-powered submarines. The missile also can be used against conventional submarines and surface vessels (Figure 16).

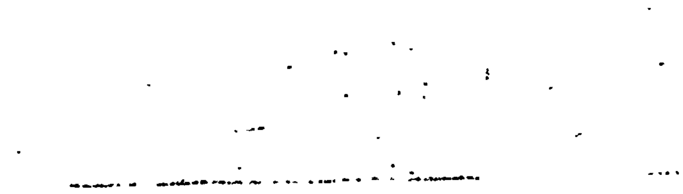

Figure 16. The antisubmarine guided missile SUBROC.

The antisubmarine missile is launched from a conventional torpedo tube in the submerged submarine. /107

SUBROC has two sections. The head is a nuclear depth bomb, the tail the engine. Launch weight of the missile is 1820 kg, body length some 6.4 m. Range supposedly is between 65 and 80 km.

The head is 330 mm in diameter and 2.96 m long, and is fitted with a nose cone. The head carries the nuclear warhead with a safety, ignition, and explosion system, the inertial guidance equipment, and the auxiliary power plant.

The end of the head has four T-shaped aerodynamic control surfaces and four rudders tilted by hydraulic servo drives. The rudders control the missile along its flight path and ensure that the head will enter the water at the ordered angle at the end of the path.

An annular flange, bolted to the front cover of the tail section, is located aft of the rudders.

The inertial control system is a gyroscopic stabilizer with a three-degree cardan suspension. Used in the system for stabilization of the platform are three floated-type integrating gyroscopes, each with one-degree of freedom, installed in a stable element. Three pendulous accelerometers, on the platform, measure the accelerations acting on the missile on the three coordinate axes.

The auxiliary power plant supplies power to the electronic gear and drives the hydraulic servo drive in the aerodynamic stabilizer control system. The plant runs off a powder gas generator from launch to missile activation. The ship's system supplies power prior to launch.

The tail section is a cylinder 533.4 mm in diameter and about 3.45 m long.

The propulsion plant is a solid-propellant rocket motor developed by Thiokol.

Three plug connections are located in the upper part of the after cover and are designed for use in making prelaunch preparations and for feeding the missile with initial data upon firing. /108

The fire-control system was developed by General Precision, and carries the conventional code designation of Mark 113. The system is based on computers that are very accurate and fast in processing firing data.

The Mark 113 system is made in the form of individual modules so it can be readily modified for installation in different classes of submarines.

The Mark 113 system provides fire control for SUBROC, and for other types of antisubmarine weapons used by submarines.

The Mark 113 system can be fed, and can process, input data from different sources. Target data is supplied from the sonar complex (AN/BQQ-2), from the radar, or from the periscope. The inertial navigation system, the electromagnetic log, the automatic plotter, depth gauge, and other navigation equipment supply data on own submarine position and movement parameters.

The Mark 113 system converts these data into present target parameters, its last position, and the lead needed for firing the antisubmarine weapon.

The results are fed into the SUBROC control system in the form of a flight program.

A Mark 130 all-purpose electronic computer is the basis of the Mark 113 system. The computer has a magnetic storage and random access. Storage capacity is 4096 twenty-valued "words."

Five continuously operating calculators are used in addition to the electronic Mark 130 computer to solve special calculation and control problems in the computing block.

If a SUBROC missile is in the torpedo tube it can be launched within a minute of detection and classification of the target by the sonar gear.

Despite the fact that the Mark 113 system is continuously processing the data needed for firing all tubes, it takes 10 seconds to launch the next missile in order to avoid an accidental collision with the preceding one. /109

The solid-propellant rocket motor is ignited one second after the missile leaves the tube. The deflectors act to bring the missile out of the water (Figure 17), after which it flies its path through the air at supersonic speed.

Deflectors, tilted by the stream of gases from the motor, in accordance with signals supplied from the head via wire from the guidance system, control the missile in pitch, course, and roll on the power leg of the trajectory. As soon as the missile has flown its programmed power leg, the tail section separates and falls into the sea, whereupon the head continue its flight over the ballistic trajectory, with flight control over this leg provided by the aerodynamic control surfaces. /110

Figure 17. Flight of a SUBROC missile. 1 - missile in motion under water; 2 - missile leaving the water on the air leg of the trajectory; 3 - missile flight over the powered leg of the trajectory; 4 - thrust reversal system energized; 5 - separation of missile head from motor; 6 - flight of missile head over the passive leg of the trajectory.

These control surfaces are jettisoned just prior to the water entry. The nose cone breaks away at the moment of impact with the water, greatly weakening the impact load attributable to the rate of fall, which is 365 m/sec. The head enters the water, sinks, and explodes at the ordered depth.

A nuclear charge is calculated to kill a submarine within a radius of approximately 2000 meters. The missile can be fitted with a conventional charge as well.

Serial production of SUBROC for the U. S. Navy began in 1965. It is supposed that over 200 such missiles have been produced. The total missile development cost was $200 mil'ion.

The foreign press, while pointing to the advantages of the SUBROC system, also noted some serious drawbacks. The rocket is launched at shallow depth and creates quite a bit of noise, revealing the position of the firing sub-

marine. Pentagon officials recently have begun to give a great deal more attention to questions concerned with killing submarines with conventional charges, as well as with nuclear charges. Requirements for accuracy in detecting and destroying a target have, as a result, be n stiffened.

Thus, it is considered that the antisubmarine weaponry created in recent years for submarine use has greatly increased their combat capabilities in the fight against the underwater enemy.

Electronic Equipment

The constant communication improvements being made in observation, weapon control, communication, and navigation systems result in a steady increase in the cost of electronic equipment, as well as in an increase in weight, in the volume occupied within ships' spaces, and in the electric power demand. Figure 18 presents data showing the change in the different types of submarine electronic equipment in the past twenty years. During this period the weight and the volume taken up by this equipment alone have increased by a factor of between 5 and 6. /111

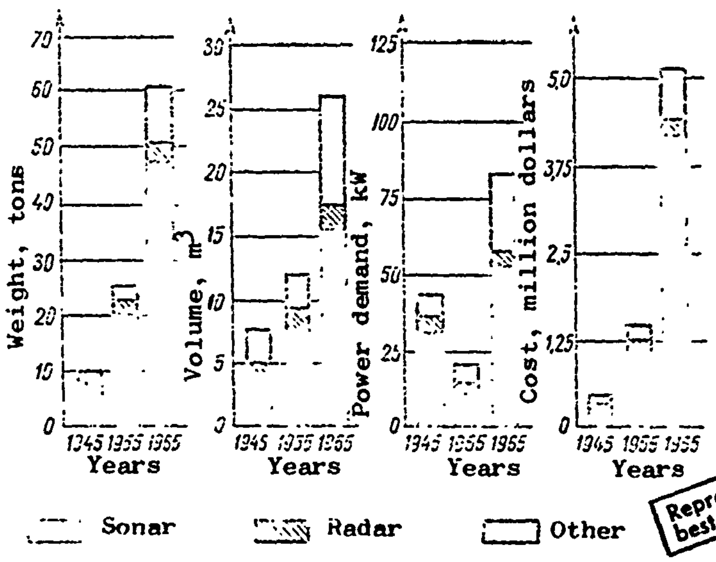

Figure 18. Comparative characteristics of electronic equipment for torpedo submarines of the U. S. Navy between 1945 - 1965.

The increase in the weight, size, and cost of electronic equipment for modern submarines has led foreign experts to the conclusion that submarines must be designed jointly with the electronics. This will result in better location of the equipment, including antennas, provide normal heating conditions, eliminate mutual interference and the negative effect of shock and vibration, provide maximum dependability and survivability of equipment in operation, and the like.

As will be seen from Figure 15, the greatest specific weight in the volume of electronic equipment aboard modern submarines is that of sonar, the importance of which has increased substantially in recent years. Sonar is the sole source of information on the surrounding situation for the submerged submarine. /112

The foreign experts are of the opinion that sonar in modern submarines results in solutions to the following primary tasks:

conduct a search for submarines and surface targets;

classify contacts made;

fix the coordinates of targets detected;

feed data into the fire control system;

provide underwater sound communication;

counter the enemy's electronic equipment;

provide for safety of navigation.

The accomplishment of these tasks with sonar under contemporary conditions required the designing of numerous complicated instruments, structurally interconnected and combined into sonar complexes.

The principal problem is considered to be the detection and classification of underwater targets, and this can be explained by the inadequate study made of conditions prevailing in the oceanic environment, and of their effect on the performance of sonar. The following example will serve to illustrate just how great this influence is. The same sonar, operating in the Toulon area, picked up the same submarine at 4000 meters in the winter, and at 800 meters in the summer.

It is a known fact that sound waves are propagated in sea water at a rate five times that in air, but the rate of propagation depends on many factors, primarily water temperature and salinity. The sound propagation rate increases 0.17% with an 0.5° increase in water temperature, by 0.07% with a 1‰ increase in salinity, and by 0.13% for each 100 meters increase in depth.

Surface waters usually are warmer than deep waters, after which the temperature falls to some constant value observed at great depth. Salinity too increases with depth to some stable value. The pressure is directly proportional to the depth. The result of the combined influence of these factors is that initially the speed of sound decreases with depth, but then increases (Figures 19, 20). /113

There are, however, areas in which local anomalies predominate over the above behavior patterns. Sound radiated by a source above, or below, the layer with lowest sound propagation rate (the sound channel) moves to this layer and is propagated along it. Consequently, if the submarine is in the

sound channel, or below it, detection probability is reduced because the sound beams from the enemy's search sonars, as well as own-ship's noise, refracting at the boundaries of the sound channel, will change their direction and will propaga e along the sound channel, or will be dissipated.

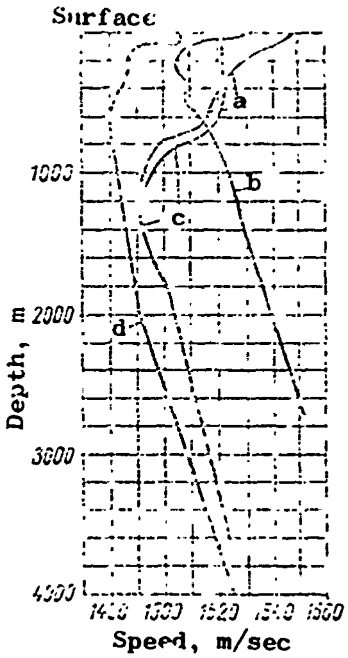

Figure 19. Speed of sound in terms of depth in different ocean areas. a - Bahama Islands; b - Mediterranean Sea; c - Atlantic Ocean; d - Pacific Ocean near California.

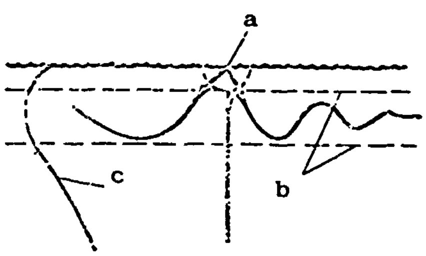

Figure 20. Influence of the sound channel on the propagation of sound in the ocean. a - sound source; b - sound channel boundaries; c - speed of sound in terms of submersion depth.

The deep-water sound channel is between 600 and 1200 meters, and as the foreign experts see it, will be accessible to the submarines of the very near future.

The surface sound channel usually is at 60 to 90 meters and stretches over a vast area, or is a small section of the water environment.

Thus, sonar for detection, classification, and fixing the position of a submarine once detected, needs precise knowledge of data on temperature,

salinity, and water density in the search area.

Also influencing the nature of propagation of sound in the ocean are the reflecting qualities of the bottom, which change with relief and bottom composition, and the water surface, the reflecting qualities of which also change with wave motion and the presence of air bubbles. A great many natural noise sources (waves, rain, sea animals, fish, and the like) have an effect on the nature of the propagation of sound waves in the sea. As we see in the press, this leads to 90 percent of targets detected today being declared false, after having been initially classified as submarines. /114

Attenuation of sound energy increases with increase in audio frequency, and this makes low-frequency audio oscillations better suited for long-range detection of submarines. Scattering of sound too changes with the presence of different dissolved salts, particles in suspension, and marine organisms.

Foreign experts are at this time devoting a considerable amount of attention to study of the peculiarities of the propagation of sound in the upper, warmer layer of the sea. Sound sometimes travels great distances in the surface sound channel. The lower boundary of the surface sound channel is the layer of sharp density gradient, below which there is a steady decrease in temperature and a sharp drop in the sound propagation rate.

The use of the hydrological peculiarities of the seas and oceans by submarines will greatly increase their capabilities for using their observation gear, as well as improving by far the conditions for using acoustic navigation systems. This increases the capability of submarines to conduct concealed search and tracking of enemy submarines.

There are those foreign experts who are of the opinion that future development of submarine detection equipment, and progress in general in many areas associated with the use and future development of submarines and naval weaponry, will depend on study and understanding of the many phenomena that take place in the ocean depths. /115

The ocean covers approximately 71% of the earth's surface and is comparatively less accessible than the atmosphere. This has increased the intensity with which oceanographic research is being conducted, and in work concerned with the study of sound propagation conditions in the ocean in particular. The United States, for example, in 1963 developed and adopted a ten year program of oceanographic study, primarily navy oriented. The proposal is to spend at least $2.2 billion on this program between 1963 and 1972.

Depths to 550 meters will be of particular interest for oceanographic research.

The process of studying and learning about the water environment can be broken down into three stages. The first is the research stage, the second the analysis of the phenomena that take place, and the third is the development of methods for making oceanographic forecasts that can play as important a role in submarine combat operations, and those of other ASW forces, as

meteorology plays in air force operations. The United States, in the estimate made by foreign experts, is only at the second of these stages, and will have to make a greater effort in order to make the transition to the forecasting stage.

It is reported that even now modern sonar with long detection range is being built on the basis of known hydrological data on the marine environment. As we see in the press, the characteristic pattern in the development of sonar systems today is one of making a transition from low frequencies to very low and ultralow frequencies, despite the fact that this will necessitate the installation in submarines of very large acoustical systems and domes. These frequencies have maximum range of propagation of audio oscillations in water.

The use of very low frequencies and the simultaneous increase in the radiation acoustic power (800 watts during World War II) to several hundred kilovolts, as well as the increase in the efficiency with which electrical /116 energy is converted into sound energy (sonar efficiency at the end of World War II was 15 to 30%; today it is 70%), the formation of narrow beams, the use of these beams for scanning in the vertical and horizontal planes, and a number of other improvements, have resulted in a sharp increase in the range at which underwater targets can be detected.

One of the best sonar complexes in foreign navies is the AN/BQQ-2, installed in all nuclear-powered multipurpose submarines in the U. S. Navy, beginning with the Permit (Thresher) class. The complex consists of the AN/BQS-6 sonar, the AN/BQR-7 listening sonar, the AN/BQA-3 indicator-computer; the AN/BQA-2 for underwater sonar communication, and the AN/BQQ-3 target classifier. The main sonar in the AN/BQS-6 complex is manufactured by Raytheon. Operation is on low frequencies in the echo-listening mode and the power is five times that of the AN/BQS-2, installed in the Skipjack class.

When noise levels are low, and hydrological conditions are favorable, the gear has a detection range of 25 km in the echo-listening mode and between 55 and 220 km in the listening mode, depending on the reflectivity and noise generated by the target. The antenna is a sphere in the bow section of the submarine hull. This shape of the antenna and transducers makes for convenient location of the antenna on the submarine's hull, the space required has a small cube, and the formation of the patterns in the horizontal and vertical planes is simplified. There are 1245 individual receiving-radiating elements made of a piezoceramic material, barium titanate, on special mounts on the surface of the sphere. Sphere diameter is 3.6 meters (4.3 meters according to other information) and the sphere is made of high-strength steel.

The AN/BQS-6 gear is located inside the pressure hull and in the pressure sphere in the bow. A manhole, connecting the sphere with the pressure hull, provides access to the inside of the sphere for maintenance of individual components.

The AN/BQS-6 can, in the echo-listening mode, provide circular and /117 sector search with electronic beam scanning in azimuth without mechanical rotation of the antenna system.

Electronic beam scanning in elevation also is envisaged, providing target detection at considerable distances by signals reflected from the ocean surface and bottom.

The AN/BQS-6 supposedly can detect targets at distances corresponding to the SUBROC firing range (over 40 km) when reception is of bottom reflections.

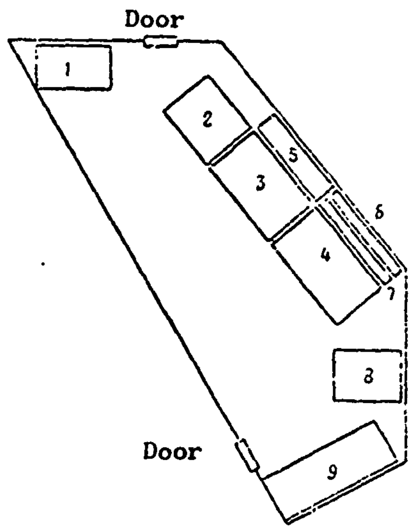

Figure 21. Arrangement of the AN/BQQ-2 equipment in the sonar room of a nuclear-powered multipurpose submarine. 1 - AN/BQA-2 console; 2 - AN/BQS-6 console; 3 - echo-listening sonar console; 4 - AN/BQA-3 computer-indicator; 5 - console for measuring and analyzing own-ship's noise; 6 - tuning filters; 7 - noise tape recorders; 8 - AN/BQR-7 console; 9 - AN/BQQ-3 console.

On the active mode console in the sonar room (Figure 21) is a large circular scan indicator on which targets are recorded and their coordinates fixed in the active circular scan mode. Only the sector being scanned appears on this indicator during directional radiation. Rotation of the pattern in the plane of scan is by the operator manually when the AN/BQS-6 is in the listening mode. A target appears on the cathode ray tube screen as a bright pip. A special recorder shows target noise graphically on the screen as a "time-bearing" function.

The information obtained by the AN/BQS-6 is fed into the AN/BQA-3, which records data on target range and bearing. These data are fed directly into the Mark 113 fire control system's computer. /118

Listening also can be done by a special listening sonar, the AN/BQR-7, the antenna system of which comprises 156 individual hydrophones located in three rows in a semielliptical arrangement in the bow (Figure 22). The system is over 15 meters in length. Recorders record signals received by the listening sonar. This is in addition to the listening that can be done with the AN/BQS-6.

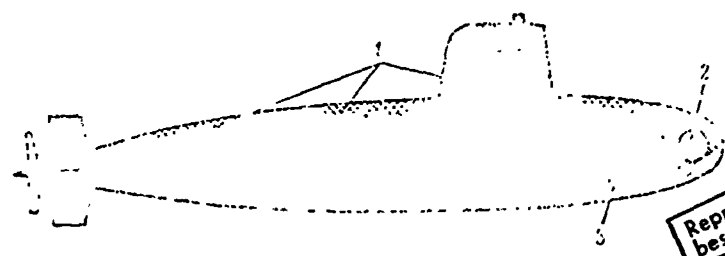

Figure 22. Arrangement of antenna systems for the sonar complex in nuclear-powered torpedo submarines.
1 - AN/BQQ-3 hydrophones; 2 - AN/BQS-6 antenna system;
3 - AN/BQR-7 antenna system.

The AN/BQQ-2 complex includes the AN/BQA-2 sonar for underwater sonar communications between submarines, and with surface vessels. It includes coding equipment so secure communications can take place over distances of up to 20 km.

The AN/BQQ-3 target classifier is a first, according to the statements made by foreign experts. Sets such as these should simplify the process of distinguishing submarine noise from all the other noise in the ocean, regardless of the method used, active or passive, to detect the submarines, because classification and identification of underwater targets are considered to be processes equal in importance to that of detection.

The tape recorder of this set records the nature of the audio radiation from the target on magnetic tape for subsequent analysis of the audio spectrum by frequency tunable filters. /119

Development of the AN/BQQ-2 complex was begun by Raytheon in 1959, and the complex was placed in serial production despite the fact that the many adverse findings during the tests of the experimental models were not corrected.

At the same time, the submarine fleets of the principal capitalist states are placing a great deal of importance on the development of passive sonar for detecting submarines and fixing their coordinates, in order to increase the secrecy with which submarines operate. The United States, for example, has developed a special system for the passive measurement of the range to noisemaking targets, known as PUFFS*. The system uses three acoustic receiving transducers located along the length of the submarine's hull.

Each of the three acoustic transducers receives the noise coming from the target with a time shift. An electronic computer uses the differences in times of arrival of the noise to calculate the position of the target and these data are fed into the fire control system. The measurement and calculation of target coordinates is automatic in the PUFFS system, according to the information in the foreign press.

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* PUFFS - Passive Underwater Fire Control Feasibility Study, is a fire control system using calculated data obtained from the use of the passive detection method.

It is suggested that two submarines operating in consort and taking bearings on a target will increase accuracy in determining target range. The accuracy of the measurements is increased because of the "baseline" along which the acoustic transducers of both submarines are spaced.

Today, preference is given to those methods using passive determination of range to the underwater target because of their secrecy, but some foreign experts believe active search for targets is more likely in the future because the work being done to make submarines noiseless makes their detection simply by listening more and more unlikely.

Nuclear-powered submarines have hydroacoustic gear in addition to that /120
listed for ancillary purposes. Modern U. S. Navy multipurpose submarines have the OSN (Own Ship's Noise) indicator for determining the level of own ship's noise. The installation includes several hydrophones at different points on the outer hull and an indicator in the sonar room.

All U. S. Navy submarines have the AN/WLR-2 equipment for hydroacoustic ranging. It is designed to pick up sonar signals, underwater sonar communications by the enemy, and radiation from active torpedo and antisubmarine missile guidance systems.

Submarines of other of the capitalist states (England, France, Sweden, the FRG, and others) also are equipped with hydroacoustic observation installations.

Sonar, in the opinion of foreign naval experts, today is the only method that can be used to solve the problem of rapid and effective detection of submarines. That is why the United States, as well as other capitalist countries, are devoting a great deal of attention to the modernization and development of submarine sonar gear.

Overall, the foreign experts believe that the fight with submarines is more a problem of detecting and classifying them than one of antisubmarine weaponry, for even in the era of nuclear missiles the decisive factor in the fight with enemy submarines will be modern detection, identification, and tracking equipment. At the same time, future progress in the development of acoustic equipment for submarine detection will depend on knowledge of the many phenomena taking place in the ocean depths.

Radar, Radio, and Navigation Equipment

Submarine electronic equipment for observation and target designation includes air and surface search radar, as well as equipment for obtaining radio intelligence and for initiating radio countermeasures.

Submarine radar serves as auxiliary equipment for obtaining information /121
and can be used on the surface, or at periscope depth.

Modern American submarines have the AN/BPS-9 radar, operating in the 2.73-5.77 cm band. British nuclear-powered submarines have radar similar to American radar, capable of transmitting data on surface target range and bearing to the automatic torpedo firing system.

Radio intelligence gathering equipment, operating in the passive mode, usually is used to conceal submarine activity. This equipment can provide valuable information on the enemy under definite conditions. The antennas of these sets are extendable.

The radio communication equipment enables the submarine to carry on two-way communications on shortwave and ultrashort wave and receive on medium, long, and superlong waves.

Standard equipment for American nuclear-powered submarines comprises an ultrashort wave radio, two shortwave transmitters, two shortwave receivers, and a receiver for long and medium-long waves. The frequency used to communicate with submerged United States submarines is 15 kHz.

The radio communications equipment has highly stable frequencies, providing for instant communication over the entire frequency band. This is achieved by the use of special circuits, high-quality components, and supply voltage stabilization. The AN/WPT-4 transmitter, 2-30 MHz, and the AN/WRR-2 receiver for telephone, teleprinter and telephoto communication, are examples of equipment of this type installed in nuclear-powered submarines. Included in the radio equipment are superhigh-speed units (storages) that increase the transmission rate to 1000 and more words per minute, and thus increase communication security.

Submarine receivers, in addition, have recorders for recording radio messages transmitted at high speed. Incoming traffic then can be listened /122
to with the tape moving at its normal rate of speed.

U. S. Navy shore-based headquarters use powerful low-frequency stations to maintain constant radio communication with nuclear-powered submarines below periscope depth. The majority of these long-wave communication stations for the American navy were built before World War II, or at the outbreak of that war. These stations are in Annapolis, Jim Creek, Balboa, Pearl Harbor, Lualailua (Hawaiian Islands), and in others places. The Americans began to use the long wave Japanese station in Yashima after the war.

The U. S. Navy today is building superpowerful radio stations (centers) in different parts of the world to communicate with nuclear-powered submarines submerged at great distances from their bases.

Some of these stations already are in use. The 2000 kW station in Cutler (Maine), for example, provides communication with submarines at depths of 30 meters in the waters of the North Atlantic Ocean and the Mediterranean Sea (Figure 23).

The U. S. Navy is studying the feasibility of using artificial earth /123
satellites with low-frequency transmitters as relays for shore and ship radio stations in order to increase the depth at which it still will be possible for submarine receivers to pick up radio signals.

The extendable submarine antenna for the long and medium-long wave receiver is designed in the form of two mutually perpendicular loop antennas with a diameter of some 50 cm.

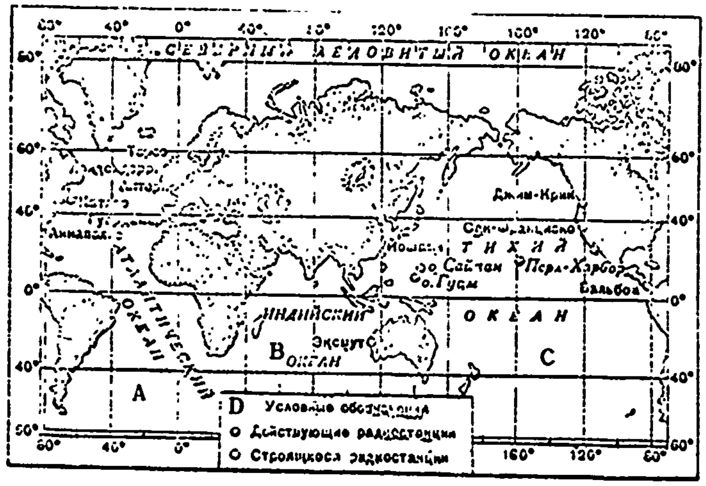

Figure 23. Locations of main radio centers in communication with submarines.
A - Atlantic Ocean; B - Indian Ocean; C - Pacific Ocean
D - Conventional Signals
● Active radio station
o Radio station under construction.

Short and ultrashort wave reception and transmission is possible only when the submarine is on the surface, or at periscope depth. The extendable antennas for this purpose are in the sail. The AN/WRA-2 type extendable antennas are telescoping masts that can be raised 8 meters above the sail. Foreign experts are of the opinion that the most difficult problem, and one that is not yet solved, is that of communication between submerged submarines and ASW forces (aircraft and surface vessels) acting in consort. The problem is further complicated by the difficulty in identifying own submarines.

Today all American nuclear-powered torpedo submarines are equipped with surfacing buoy antennas, the housings of which are made of plastic. These antennas can be used when the submarine is running submerged, or stopped. While this innovation does permit the submarine to establish communication with aircraft and surface vessels under predetermined conditions, it should be pointed out that surfacing buoy antennas do restrict the submarine's freedom of maneuver and do not ensure uninterrupted and dependable communication with the forces acting in consort.

Work is in progress on maintaining communication between submarine and aircraft by using sonobuoys. The buoy, floating on the surface, picks up the high, or ultrahigh-frequency signals from the aircraft, modulates them with audio frequency, and transmits them under water (or vice versa). Joint ASW operations involving a patrol plane and a submarine can be quite effective when they have dependable communication between them. /124

It should be pointed out, however, that the present sonobuoys for this type of communication are far from perfect and do not meet the demands imposed upon them.

Serially built nuclear-powered U. S. Navy submarines are equipped with AN/WIC gear, a complex interior communication system that includes the following announcing subsystems:

general ship command;

engineering division;

emergency communications;

submarine control;

general interior communication;

rescue (exit) hatches.

The system also includes emergency and general alarm signal generators. Nickel-cadmium batteries provide a few hours of emergency power for the system. Transistors and modules are widely used for interior communication systems.

The long underwater endurance of nuclear-powered submarines, and the possibility of their combat use in the high latitudes, has led to the need to design special navigation systems and steering instruments for these ships. The U. S. Navy has given particular attention to improvements in navigation equipment for submarines because naval leaders put particularly great faith in this type of ship.

Specifically, nuclear-powered torpedo submarines use three independent, but mutually monitored, dead-reckoning systems to fix geographic coordinates. One is the ship's inertial navigation system, SINS, the other two are standard dead-reckoning tracers using gyrocompass and log inputs. Dead-reckoning system readings are evaluated automatically and, depending on their accuracy and reliability, are taken into consideration in processing averaged coordinates.

Any inertial navigation system operates on the following principle. A platform, stabilized in space, forms some fixed system of coordinates. /125

Pendulous instruments, accelerometers, installed on this platform measure accelerations in the direction of one of the three coordinate axes. Accelerometer readings, which are proportional to the accelerations, are computer processed to determine the distance traversed along each of the axes. These distances are converted into latitude and longitude differences, and, after they are added to the original coordinates, provide present submarine coordinates.

The accuracy of SINS readings depends on how long the system has been in operation, so corrections, obtained from observations made by radio aids to navigation, or from astronomical observations, must be introduced into the system from time to time.

During the transpolar passage of Nautilus the discrepancy between the dead-reckoning and the observed coordinates was 10 miles after an under-ice passage of 1830 miles.

The Mark 2 Mod. 2, or the more improved Mark 3 Mod. 3, inertial navigation systems have been installed in the multipurpose U. S. Navy nuclear-powered submarines of the Permit (Thresher) class, and in their subsequent modifications.

The navigation equipment for modern U. S. Navy torpedo submarines also includes the Loran-A receiver-indicator, or the medium-frequency Loran.

The hyperbolic Loran-A radio navigation system fixes the ship's position within ±5.5 km when 1300 km from the shore transmitting stations.

The operating frequency is 1.65-1.95 MHz, so the submarine must be on the surface, or at periscope depth, in order to receive the signals.

The type AN/UPN-12 receiver-indicator equipment has now been accepted for multipurpose American submarines. This equipment can receive the Loran-C phase difference-ranging system, which can provide a more accurate fix at distances of 3500-4000 km.

The main gyrocompass for U. S. Navy nuclear-powered submarines is the single-rotor Sperry Mark 19, accurate to within 0.1° in the middle latitudes. /126
The submarines also have a standby gyrocompass, the Mark 23, a Mark 21 vertical gyro, a gyrosyn compass, the Gyrosyn S-11, combining the principles of magnetic and gyroscopic course indication, and, finally, as emergency equipment, a Magnesyn magnetic compass.

The Sperry electromagnetic log is a new piece of navigation gear for modern American submarines. This log is mounted flush with the hull, and speed readings are supplied from the log directly to the navigation equipment, fire control instruments, and to the turbine room. A Pitot tube for measuring ship's speed is included in the equipment.

A shaft with an electromagnet that generates a field is installed in this tube. The movement of the field through the water induces an electric current, the strength of which is recorded by special heads in the end of the Pitot tube. The magnitude of the voltage generated in this way is the ship's speed, and then the speed is converted into course made good by integration.

Included in the hydroacoustic navigation equipment for submarines is the AN/UQN-1 fathometer capable of measuring depths at any point in the world ocean. In addition, all U. S. Navy nuclear-powered torpedo submarines have been equipped with two type AN/BQN-4 ice fathometers for Arctic navigation.

It is the opinion of American experts that the contemporary level of development of radio engineering equipment for observation and communication, and of navigation systems and navigation outfit, ensure the combat use of submarines in any latitude of the seas and oceans, and provides them with operational security.